CORRELATION AND SOURCE DIRECTION OF GREEN RIVER FORMATION TUFFS IN SAN PETE COUNTY, UTAH

A Thesis

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by

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ABSTRACT

Tuffs in the Eocene Green River Formation from San Pete County in central Utah have been examined in three detailed stratigraphic sections and fourty-one petrographic thin sections. The Green River Formation can be divided into a lower member dominated by mudstone and an upper unit dominated by limestone, both of which are mainly lacustrine in origin. Interbedded throughout the formation are numerous, thin, air-fall tuffs. Primary tuff minerals in order of decreasing abundance are biotite, hornblende, potash feldspar, and quartz with accessory muscovite and sphene. Secondary (diagenetic) minerals include calcite, zeolite, pyrite, and clays. Glass shards are rarely recognizable since virtually all glass has been altered to zeolites and related minerals. Nevertheless, it is believed that the mode of the tuffs was originally dominated by glass particles. Criteria for correlation of tuff beds include petrographic characteristics, hornblende:biotite ratios, the ratio of total primary minerals to combined groundmass and secondary minerals, stratigraphic interval, and thickness. Based on the correlation of three prominent tuff beds, it is concluded that the contact between the upper and lower members of the Green River Formation is distinctly time transgressive, and that the source areas for volcanic detritus is north or northeast of the San Pete Valley.

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INTRODUCTION

The purpose of the investigation reported in this paper was to correlate tuff beds in the Green River Formation in San Pete County, Utah (Fig. 1) and to determine the direction of the volcanic source. Three stratigraphic sections, which are named White Hill, South Baldy, and North Hollow (Plate I), were carefully measured in detailed fashion. The White Hill section was measured on a cuesta four miles northeast of Ephraim, Utah in San Pete Valley (SE 1/4, Sec. 24, T16S, R3E). The section at South Baldy is located nine miles east of Ephriam on the Gunnison Plateau (SE 1/4, Sec. 36, T16S, R1E). The North Hollow section is located nine miles south of Manti on the Wasatch Monocline (SE 1/4, Sec. 26, T19S, R2E). Fourty-one thin sections of the tuffs collected in these stratigraphic sections were examined with a petrographic microscope.

Field work was performed during the Summer of 1969 while attending the Summer field camp of the Department of Geology, The Ohio State University. Laboratory work was done during the Autumn Quarter 1969, on the Ohio State University Campus in Columbus, Ohio.

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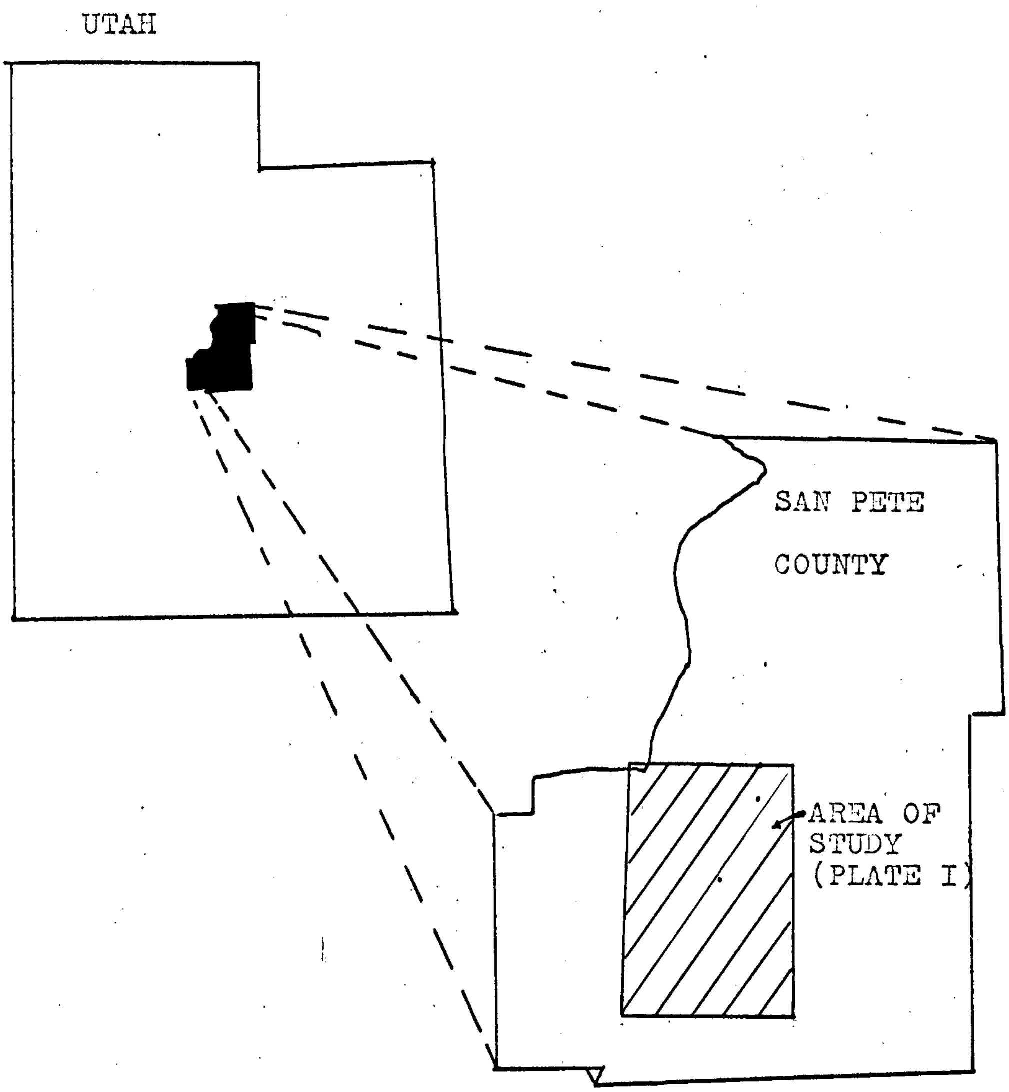


Figure 1. Index map of San Pete County, Utah. Rand McNally, Standard Map of Utah, 1:963,100.

STRATIGRAPHY

General Tertiary Stratigraphy

In order of decreasing age the Tertiary section of San Pete Valley, Utah consists of the North Horn Formation, Flagstaff Limestone, Colton Formation, and the Green River Formation as defined by Spieker (1946).

The North Horn Formation, which is in part Late Cretaceous, consists of fluvial red sandstone and conglomerates, and lacustrine mudstone and limestone. It grades into the overlying Flagstaff Limestone, which consists of massive, arenaceous, lacustrine limestone in the lower part and interbedded limestone and mudstone in the upper part. The Flagstaff Limestone is conformably overlain by the Colton Formation, which consists of lacustrine white to light gray limestones, red and green mudstones, and brown channel sandstones. The Colton Formation contacts are intertongued with the Flagstaff Limestone Member and the overlying Green River Formation. The lacustrine Green River Formation differs from the Colton Formation by lack of red color and preponderance of limestone. The Green River Formation consist of lacustrine mudstones and limestones, fluvial green sandstones, and air-fall tuffs. The Green River Formation is disconformably overlain along a sharp contact by the Crazy Hollow Sandstone, which shows characteristic salt and pepper texture.

Green River Formation

The Green River Formation is divided into a lower member and an upper member. The lower member consists mainly of lacustrine green, gray, and brown mudstones with a few interbedded limestone beds and lenses of coarse-grained, green sandstone. The basal unit is mainly sandstone and green mudstone. Brown mudstone increases upward in the section and air-fall tuff beds become more prevalent. The contact between the upper and lower member is distinct; it is picked at the first massive, cliff-forming limestone above the green mudstone. The limestone may be sublithographic, crystalline, or algal. The upper part of the upper member is interbedded limestone, and green and brown mudstone finally becoming mainly mudstone. The contact of the Crazy Hollow Sandstone is very distinct. Tuff beds are found throughout the Green River Formation, but are mainly concentrated in the upper part of the lower member of the Green River Formation.

Comparisons of Measured Sections

The lithologies of the three sections measured are much the same; however, some systematic differences were noted. The upper member of the Green River Formation at North Hollow contains more limestone than the section at White Hill. At White Hill the lower member of the Green River Formation is mainly brown mudstone, whereas the other two sections are mainly green mudstone. Furthermore, the White Hill section contains the greatest number of tuff beds. At South Baldy the amount of limestone in the basal part of the lower member of the Green River Formation is greater than in the other two sections. The three columar sections are shown on Plate I.

GREEN RIVER TUFFS

Introduction

The tuff beds are mainly concentrated in the upper half of the lower member of the Green River Formation. They make up 1-2% of the total Green River section; 90% of the tuff beds are in contact with mudstone. Recognition criteria used in the field are the presence of megascopic biotite and hornblende, volcaniclastic texture, and the response to weathering.

Field Characteristics

The tuff beds are homogeneous in appearance and form resistant ledges, which break up perpendicular to the bedding into blocky fragments, and weather to brown or light buff, but some tuffs are light green or gray. Beds range from 0.5 to 28 inches in thickness; within the lateral extent of a single outcrop variation in thickness is approximately 15% at a maximum.

The upper and lower contacts of the tuff beds are usually distinct and abrupt. In some cases the lower contact is characterized by a thin layer of friable, highly concentrated, crystalline material. The upper contact is typically marked by a thin zone of interbedded tuff and mudstone.

Hand Sample Characteristic

Fresh hand samples are grey, green, or pale yellow. Tuffs with abundant primary minerals are grayish yellow. Weathering produces color variations within a single hand sample. Random orientation of biotite and hornblende grains is typical, but some samples do exhibit lineation and planar orientation parallel to bedding. Graded bedding is rare, but hornblende and biotite exhibit increasing concentration towards the base of individual beds (Plate

III., Fig. 2). Biotite and hornblende are the only identifiable minerals in hand sample.

Petrography

The tuffs range from crystal to vitric, but most samples are vitric-crystal tuffs. Actually, glass is no longer present because of devitrifacation and alteration.

The primary minerals biotite, hornblende, quartz, and feldspar are present in every sample, but in the case of the vitric tuff the primary minerals are rare. Biotite is euhedral, fresh, and ranges in size from 0.16 mm. to 0.80 mm. It shows dark-brown to brownish-yellow pleochroism, which suggest a high iron content. In some cases the grains of biotite are torn or distorted, but still retain their euhedral characteristics. The amount of biotite ranges from a trace to 12 per cent.

Hornblende is euhedral, fresh, and ranges in size from 0.08 to 0.80 mm. Pleochroic colors are dark green to yellow or light green. The percentage of hornblende ranges from a trace to 12 per cent.

Quartz is anhedral to subhedral with high sphericity and angular edges. Quartz is partially replaced in many cases by zeolite (Plate II, Fig. 4), and rarely by carbonate. The percentage of quartz ranges from a trace to 8.4 per cent.

Feldspar is euhedral to subhedral, and ranges in size from 0.08mm. to 1.0mm. It is partially replaced by zeolites (Plate II, Fig. 2) and rarely by carbonate. The percentage of feldspar ranges from a trace to 16 per cent.

Secondary minerals, most of which are probably diagenetic, include calcite, zeolite, pyrite, and clays. Microcrystalline calcite replaces feldspar, quartz, and groundmass, and varies in abundance from none to 14.0 per cent. Zeolite replaces feldspar, quartz, groundmass and glass shards (Plate II., Fig. 3). The zeolite is replaced in some cases by calcite, which indicates that the zeolite formed before the calcite. Abundance of zeolite ranges from a trace to 17.2 per cent. Pyrite shows good cubic form, but in most cases it is altered to hematite, staining the adjacent material red. Size varies from 0.04 to 0.8 mm., and varies in abundance from none to 1.6 per cent.

Cryptocrystalline clay minerals occur in the groundmass and vary in color from yellow to green. Green clay minerals are common in rocks in which shard structures are replaced by zeolite. Clay minerals are believed to be the result of weathering of glass particles, although some of the clay might be diagenetic.

Originally the tuffs contained a high amount of glass shards and dust. Alteration has destroyed almost all evidents of prexisting glass except in unusual cases where replacement by zeolite has preserved shard structure. Shard structure occurs only in light green tuffs. In the case of the light green tuff the amount of glass replaced by zeolite is high. The glass shards are of various sizes and shapes (Plate II., Fig. 3).

In plane polarized light the cryptocrystalline groundmass is yellow, light to dark brown, gray, or green, but it is nearly isotropic under crossed nicols. The groundmass probably consists of mainly extremely fine-grained clay, zeolite, and calcite.

The only minerals showing preferred orientation are biotite and hornblende although they are typically randomly oriented. The rose diagrams (Fig. 2,3,4,5,6, and 7) show the plotted orientation of two samples;

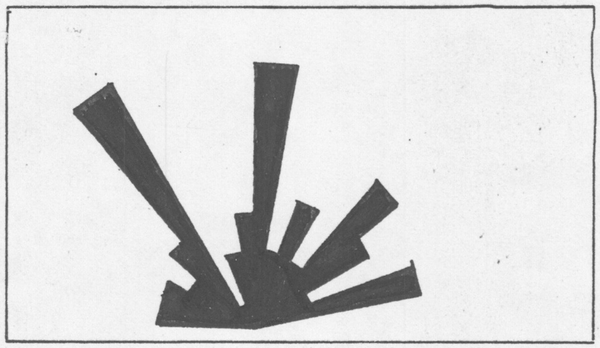
megascopic random sample WH-5 (Fig. 2, 3, and 4), and magascopic preferred orientation sample WH-19 (Fig. 5, 2, and 7). The three thin sections of each sample are cut perpendicular to each other, with section c parallel to the bedding plane. The rose diagram of WH-5 show no preferred orientation in Figure 2 and Figure 3, whereas Figure 4 shows a weak direction of lineation. Sample WH-19 (Fig. 5, 6, and 7) shows in Figure 5 and Figure 6 a strong preferred planar orientation, and Figure 7 a moderately strong lineation. The samples with a preferred orientation and were deposited by settling into a lake.

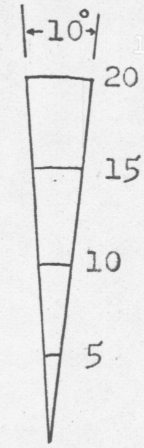
CORRELATION OF THE TUFF BEDS

Three prominent tuff beds were correlated (Plate I): bed 1 (sample NH-19, WH-6 and SB-2); bed 2 (sample NH-10, WH-3,4,5, and SB-4); and bed 3 (sample NH-12, WH-16, and SB-14). Criteria for correlation include (Table 2, 3, 4, and 5);

1. Stratigraphic interval
2. Thickness
3. Color
4. Amount of hornblende and biotite
5. Hornblende:biotite ratio
6. Ratio of total primary minerals to combined groundmass and secondary minerals

Generally, each bed correlated exhibits a distinct matrix of the correlation criteria. No attempt was made to correlate tuff beds that did not show characteristic or distinctive features. A tuff bed in one section





Scale-Fig. 2, 3, and 4.

Figure 2. Rose diagram of 100 biotite flake orientations, 10° interval, sample WH-5A, thin section cut normal to bedding and perpendicular to thin section WH-5B. Diagram shows no direction of preferred orientation.

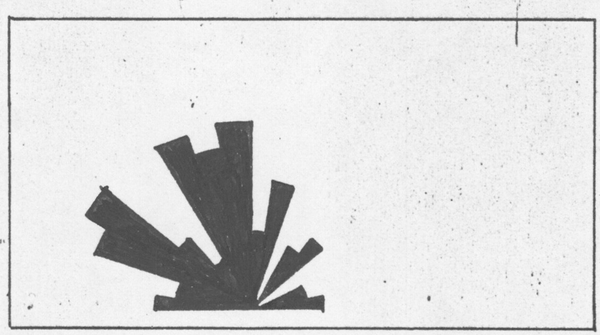


Figure 3. Rose diagram of 100 biotite flake orientations, 10° interval, sample WH-5B, thin section cut normal to bedding and perpendicular to thin section WH-5A. Diagram shows no direction of preferred orientation. Five flakes had no distinguishable direction of orientation.

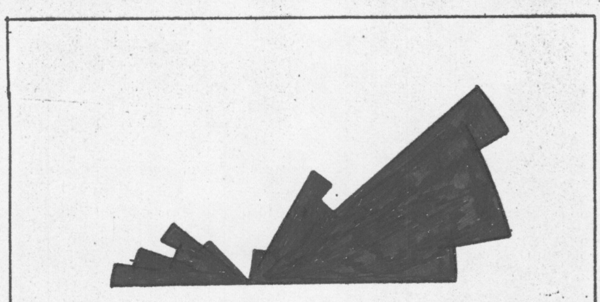
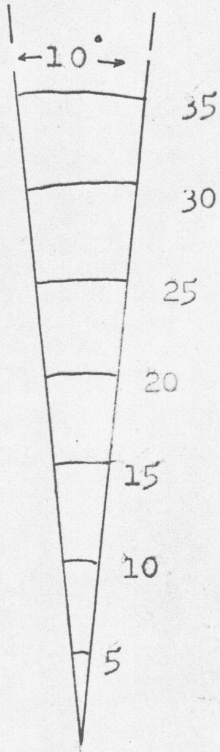


Figure 4. Rose diagram of 100 biotite flake orientations, 10° interval, sample WH-5C, thin section cut parrallel to the bedding. Diagram shows a weak direction of lineation. Two flakes had no distinguishable direction of orientation.



Scale
Fig. 5, 6,and 7.

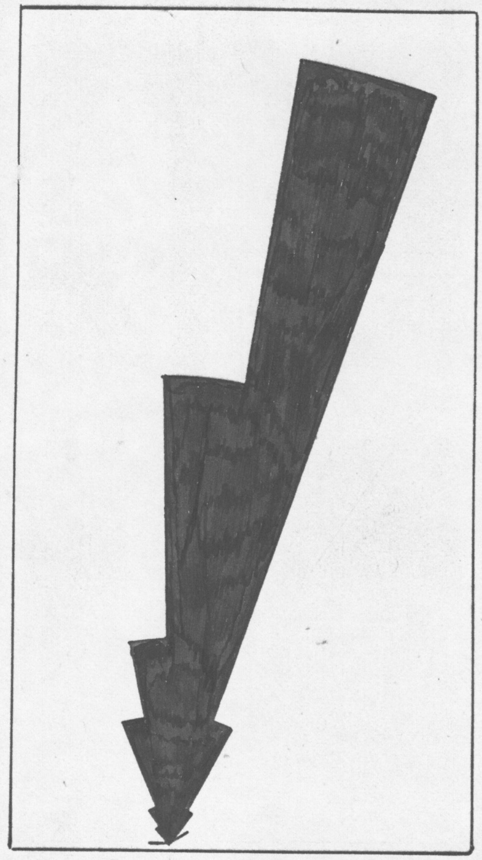


Figure 5. Rose diagram of 100 biotite flake orientations, 10° interval, sample WH-19B, section cut normal to bedding and perpendicular to thin section WH-19A. Diagram shows strong preferred planar orientation.

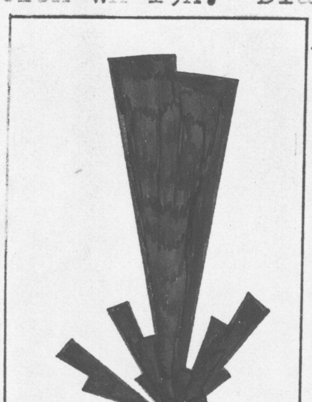


Figure 6. Rose diagram of 100 biotite flake orientation, 10° interval, sample WH-19A, thin section cut normal to bedding and perpendicular to thin section WH-19B. Diagram shows strong preferred planar orientation.

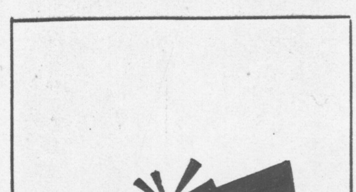


Figure 7. Rose diagram of 100 biotite flake orientations, 10° interval, sample WH-19C, thin section cut parrallel to the bedding. Diagram shows moderately strong lineation. Seventy flakes had no distinguishable direction of orientation.

Table 1. Mode Anaylsis of Bed 1, 2, and 3 (500 count, click stage, 4mm. interval)

	Bed 1			Bed 2					Bed 3		
Sample	NH-9	WH-6	SB-2	NH-10	WH-3	WH-4	WH-5	SB-4	NH-12	WH-16	SB-14
Groundmass	68.2%	63.4%	40.2%	88.0%	55.6%	80.2%	58.8%	60.2%	81.2%	68.0%	73.8%
Biotite	7.4%	8.4%	11.2%	1.8%	7.4%	4.8%	6.8%	4.6%	5.2%	4.4%	3.8%
Hornblende	4.0%	6.0%	6.8%	2.6%	12.0%	5.8%	9.0%	6.8%	trace	trace	0.2%
Quartz	2.6%	6.2%	8.4%	1.4%	4.6%	0.8%	5.0%	4.6%	2.2%	4.0%	3.0%
Feldspar	2.4%	7.0%	16.0%	1.8%	9.2%	3.2%	9.8%	5.8%	2.8%	3.6%	3.6%
Zeolite	8.0%	17.2%	14.6%	2.0%	7.2%	1.2%	7.8%	17.4%	8.0%	17.2%	14.6%
Pyrite	1.0%	0.6%	0.8%	0.0%	1.4%	1.6%	1.0%	0.6%	0.6%	0.0%	0.8%
Carbonate	9.6%	0.6%	0.0%	2.4%	2.6%	2.4%	1.8%	0.0%	0.0%	2.8%	0.2%

Table 2. Correlation and Source Direction Criteria of Bed 1.

Sample	NH-9	WH-6	SB-2
Stratigraphic Interval	65 ft.	72 ft.	80 ft.
Thickness	8 in.	6 in.	9.5 in.
Color	gray	gray yellow	gray
Amount of Biotite and Hornblende	11.4%	14.4%	27.8%
Hornblende:Biotite ratio	0.541	0.714	0.607
Ratio of total primary minerals to combined groundmass and secondary minerals	0.196	0.381	0.735

Table 3. Correlation and Source Direction Criteria of Bed 2.

Sample	NH-10	WH-3	WH-4	WH-5	SB-4
Stratigraphic Interval	79 ft.	79 ft.	79 ft.	79 ft.	83 ft.
Thickness	11 in.	27 in.	27 in.	27 in.	25 in.
Color	yellow green	yellow	yellow	yellow	yellow
Amount of Biotite and Hornblende	4.4%	19.4%	10.6%	15.8%	11.4%
Hornblende:Biotite rario	1.44	1.62	1.21	1.33	1.48
Ratio of total primary minerals to combined groundmass and secondary minerals	0.082	0.496	0.171	0.441	0.201

Table 4. Correlation and Source Direction Criteria of Bed 3.

Sample	NH-12	WH-16	SB-14
Stratigraphic Interval	79 ft.	79 ft.	83 ft.
Thickness	6.5 in.	11 in.	2 in.
Color	green yellow	green	brown yellow
Amount of Biotite and Hornblende	5.2	4.4	4.0
Hornblende:Biotite ratio	0.0	0.0	0.052
Ratio of total primary minerals to combined groundmass and secondary minerals	0.113	0.136	0.118

Table 5. Correlation and Source Direction Criteria of each Section

Section	North Hollow	White Hill	South Baldy
Total thickness of tuff beds from bed 1 to bed 3	40.5 in.	96.5 in.	94.5 in.
Total number of tuff beds from bed1 to bed 3	4	10	10

may not be identifiable in another section because of erosion, reworking, or mixing during or shortly after deposition. Consequently, many tuff beds cannot be definitely correlated from one section to another.

The stratigraphic interval between dominate tuff beds was used initially to make tentative correlations. In the case of a lacustrine environment the interval is expected to be fairly consistent. The stratigraphic interval between beds 1, 2, and 3 exhibit this consistency (Table 2, 3, and 4).

Examination of the thickness of individual tuff beds revealed that bed 1 is the thickest tuff in the lower member of the Green River Formation. However, bed 2 is the thickest in each entire section. No correlation by thickness was possible of bed 3, for it shows a large variation in thickness.

Hand samples of each bed are generally the same color (Table 2, 3, and 4), and are distinguishable megascopically on the basis of the quantity of hornblende and biotite (Table 2, 3, and 4).

The hornblende:biotite ratio of each bed is fairly consistent. The ratio of bed 1 is less than one, bed 2 is greater than one, and bed 3 is slightly greater than zero (Table 2, 3, and 4). The ratio of total primary minerals to combined groundmass and secondary minerals is very consistent in bed 3. Bed 1 and 2 vary between sections, but bed 1 generally contains a larger per cent of primary minerals than bed 2.

SOURCE DIRECTION OF VOLCANIC MATERIAL

The direction of the volcanic centers that produced the ash of the tuff beds is to the northeast from San Pete Valley. Criteria for this conclusion include (Table 2, 3, 4, and 5);

1. Hornblende:biotite ratio
2. Ratio of total primary minerals to combined groundmass and secondary minerals
3. Thickness of the beds
4. Total thickness and number of tuff beds between bed 1 and bed 3

Hornblende tends to settle more rapidly out of the air than biotite, due to its higher specific gravity and less aerodynamic shape. Therefore, a decreasing hornblende:biotite ratio is inversely proportional to the distance from the source area. The ratios of bed 1, 2, and 3 are largest at White Hill, less at South Baldy, and least at North Hollow (Table 2, 3, and 4), which infers a source direction to the northeast.

A decreasing ratio of total primary minerals to combined groundmass and secondary minerals (Table 2, 3, and 4) is inversely proportional to the distance from the source. The primary minerals tend to be larger in size and greater in density than glass particles, which probably made up most of the groundmass of the tuffs. Therefore, the primary minerals tend to settle out more rapidly. For bed 2 and 3 the ratios are largest at White Hill, less at South Baldy, and least at North Hollow, which indicates a source direction to the northeast. However, on the basis of these ratios for bed 1 South Baldy should be closer to the source than White Hill. This discrepancy can probably be explained by abnormal meteoric conditions, such as local storm conditions at the time of the ash fall. More extensive diagenetic alteration of bed 1 at White Hill than at South Baldy may also be a factor.

In general, the closer to the source, the more ash will be deposited. Therefore, the direction of increasing thickness will indicate the source direction. Bed 1 is thicker to the northwest; bed 2 is thicker to the northeast; and bed 3 is thicker to the north. The slight disagreement in the direction of the source can be explained by differential partial erosion, or reworking and mixing. The total number of tuff beds and the total thicknessof tuff will increase in the direction of the volcanic source. This is because some air-fall tuff will not be as extensive as other and a larger amount of volcanic material will be nearer the source. The total thickness and total number of tuff between bed 1 and bed 3 is greatest at White Hill, less at South Baldy, and least at North Hollow (Table 5), which indicate a source direction to the northeast.

The Green River Formation to the north and northeast contain larger tuff beds than in San Pete Valley (Dane, C. H., 1954) and (Moussa, M. T., 1969). These facts strengthen the conclusion of the northeastern source direction.

REFERENCES CITED

Dane, C. H., 1954, Stratigraphy and facies relationships of Green River Formation, and lower part of Uinta Formation in Duchesne, Uintah, and Wasatch Counties, Utah: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 405-425.

Moussa, M. T., 1969, Green River Formation (Eocene) in the Soldier Summit Area, Utah. Geol. Soc. Amer. Bull., v. 80, p. 1737-1748.

Spieker, E. M., 1946, Late Mesozoic and Early Cenozoic history of central Utah; U. S. Geol. Surv., Prof. Paper 205-D, p. 117-161.